TC^4 Aircraft Science Mission for Validating and Using Aura/CloudSat/Calipso Data in the Tropics

Brian Toon

Department of Atmospheric and Oceanic Sciences

University of Colorado, Boulder

Dave Starr

NASA Goddard

Wed. Sept 13, 2006

- **Who-**
  - Program Scientists-Mike Kurylo, Hal Maring
  - Mission Scientists-Brian Toon, Dave Starr
  - Platform Scientists
    - DC-8 -Eric Jensen, Mark Schoeberl
    - ER-2 -Paul Newman, Steve Platnick
    - WB-57-Paul Wennberg, Steve Wofsy
  - Satellite Mission Support
    - Aura-Mark Schoeberl, Anne Douglas
    - CALIPSO-Chip Trepte
    - CloudSat-Jay Mace
    - Aqua-Steve Platnick
- **What-**TC^4=Tropical Composition, Clouds and Climate Coupling experiment.
- **When-**July-Aug. 2007
- **Where-**Costa Rica

Why

Major Questions
1. How can space-based measurements of geophysical parameters, particularly those known to possess strong variations on small spatial scales (e.g., H_2O, cirrus), be validated in a meaningful fashion?
2. How do convective intensity and aerosol properties affect cirrus anvil properties?
3. How do cirrus anvils, and tropical cirrus in general, evolve over their life cycle? How do they impact the radiation budget and ultimately the circulation?
4. What controls the formation and distribution of thin cirrus in the Tropical Tropopause layer, and what is the influence of thin cirrus on radiative heating and cooling rates, and on vertical transport?

Why (contd.)

Detailed Major Questions
5. What are the physical mechanisms that control (and cause) long-term changes in the humidity of the upper troposphere in the tropics and subtropics?
6. What are the chemical fates of short-lived compounds transported from the tropical boundary layer into the Tropical Tropopause layer. (i.e., what is the chemical boundary condition for the stratosphere?)
7. What are the mechanisms that control ozone within and below the Tropical Tropopause Transition layer?
8. What mechanisms maintain the humidity of the stratosphere? What are the relative roles of large-scale transport and convective transport and how are these processes coupled?

Why choose Costa Rica in summer?

Costa Rica summertime:

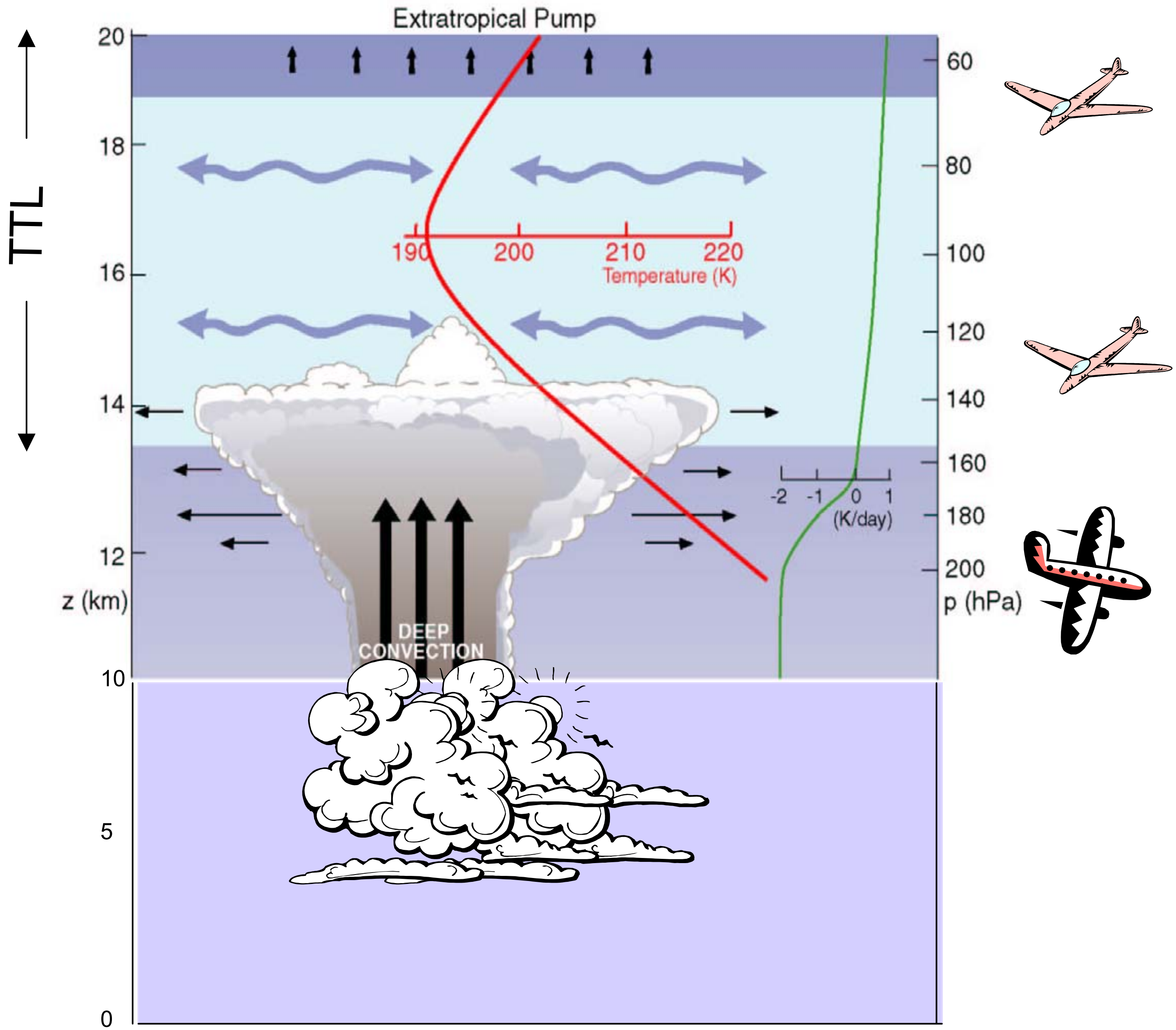
- reliable, forecastable deep convection
- both maritime and continental convection in range
- need to sample summertime TTL to understand annual cycle of water vapor during the tropical “wet phase”
- Good access to anvil cirrus for CALIPSO and CLOUDSAT cal/val

How does Costa Rica 07 differ from CRAVE (Costa Rica, January 06)?

- CRAVE (2006) focused on cloud microphysics (mainly in sub-visible cirrus), and TTL trace gas distributions. Only one aircraft participated. Campaign was conducted in the dry season (Jan-Feb), and very little cirrus was available for sampling.

- Costa Rica in July 2007 will involve remote sensing instruments, multiple aircraft, anvil studies and CloudSat/Calipso validation.

Sampling strategy-Costa Rica



Remote Sensing-ER-2

Cloud physics,
TTL chemistry
WB-57f

Cloud physics,
TTL chemistry,
Remote sensing
DC-8

Possible ER-2 payload

T, P,winds
Temperature profiler
O_3
H_2O vapor
Cloud/aerosol lidar
94 GHz radar
Precip. Doppler radar
Infrared Spectrometer

MAS
Sub-mm Radiometer (325-874GHz)
Microwave radiometer (~10-350GHz)
Solar spectral flux
Broadband IR, Solar flux
GPS downlink

WB-57 payload proposed

T, P,winds
Temperature profile
O_3
H_2O vapor (2)
CO, CH_4 and/or N2O
Aerosol size distribution
H_2O total (CVI+alternate)
Clouds particle size (1-1000µm)
Cloud Particle habit
Cloud extinction

NOx
HNO_3
HO_x
HCl
H_2O isotopes
Whole air sampler (N_2O, CFCs, CH_4-CH_3Br-CH_3I-etc.)
BrO, ClO
GPS downlink

DC-8 payload proposed

T, P, winds
Temperature profile
O_3
Ozone lidar nadir
Ozone lidar zenith
H2O lidar nadir
H2O lidar zenith
H_2O vapor
CO, CH_4 or N2O
H_2O total (CVI+alternate)
Aerosol size distribution

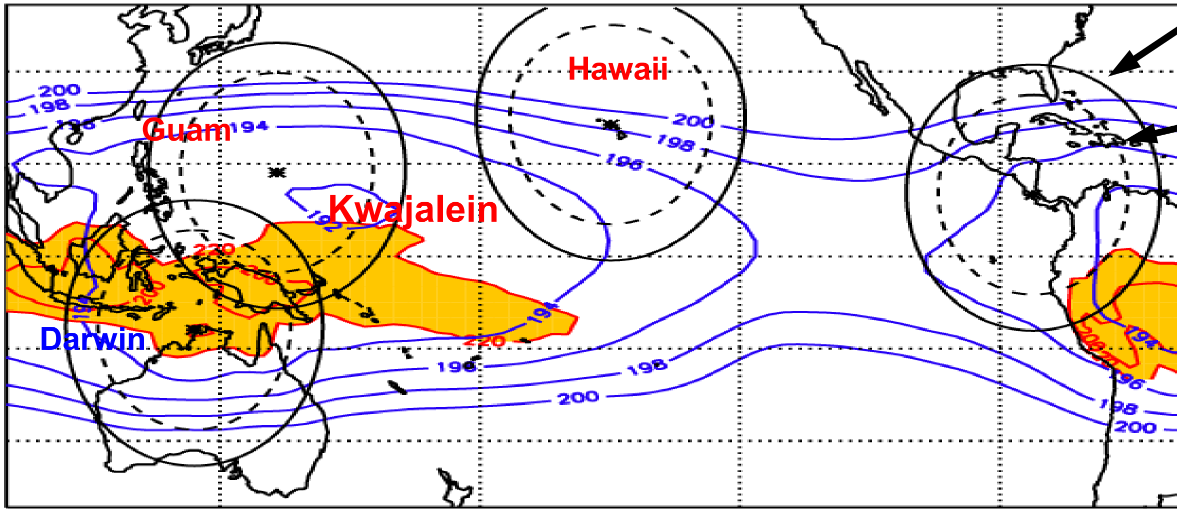
H2O isotopes
Ice Nuclei
Clouds particle size (1-1000μm)
Cloud Particle habit
Cloud extinction
Precipitation radar
Microwave radiometer
Lightning instr.
Dropsonde

NOx
HNO_3
Acetone and PAN
HO_x
HCHO,HOOH,CH_3OOH
Whole air (N_2O, CFCs, CH_4-CH_3Br-CH_3I-etc.)
GPS downlink

©GraphicMaps.com
Gulf of Mexico
Mexico
Caribbean Sea
Jamaica
Ambergris Cay
Belize
Turneffe Islands
Belmopan
Gulf of Honduras
Bahia Islands
Atlantic Ocean
Guatemala
Honduras
Guatemala
Tegucigalpa
San Salvador
El Salvador
Nicaragua
Providencia Is. (Colombia)
Gulf of Fonseca
Lake Managua
Managua
San Andres Is. (Colombia)
Maiz Islands (Nicaragua)
CENTRAL AMERICA
Lake Nicaragua
Costa Rica
Bocas del Toro (Panama)
150 mi
150 km
PANAMA CANAL
Gulf of Nicaya
San Jose
Mosquito Gulf
Panama City
Panama
Gulf of Panama
Coiba Island
Pacific Ocean
SOUTH AMERICA
Colombia
N
18° N
15° N
12° N
9°N
6°N
90° W
87° W
84° W
81° W
78° W

Climatological 100 hPa Temperature

JANUARY



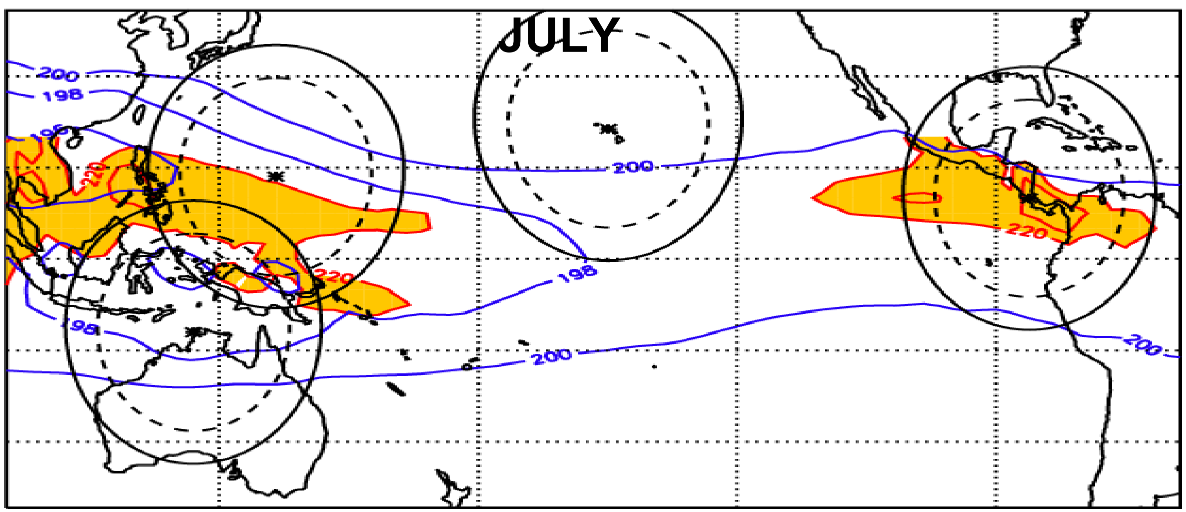
ER2 Radius of Operation

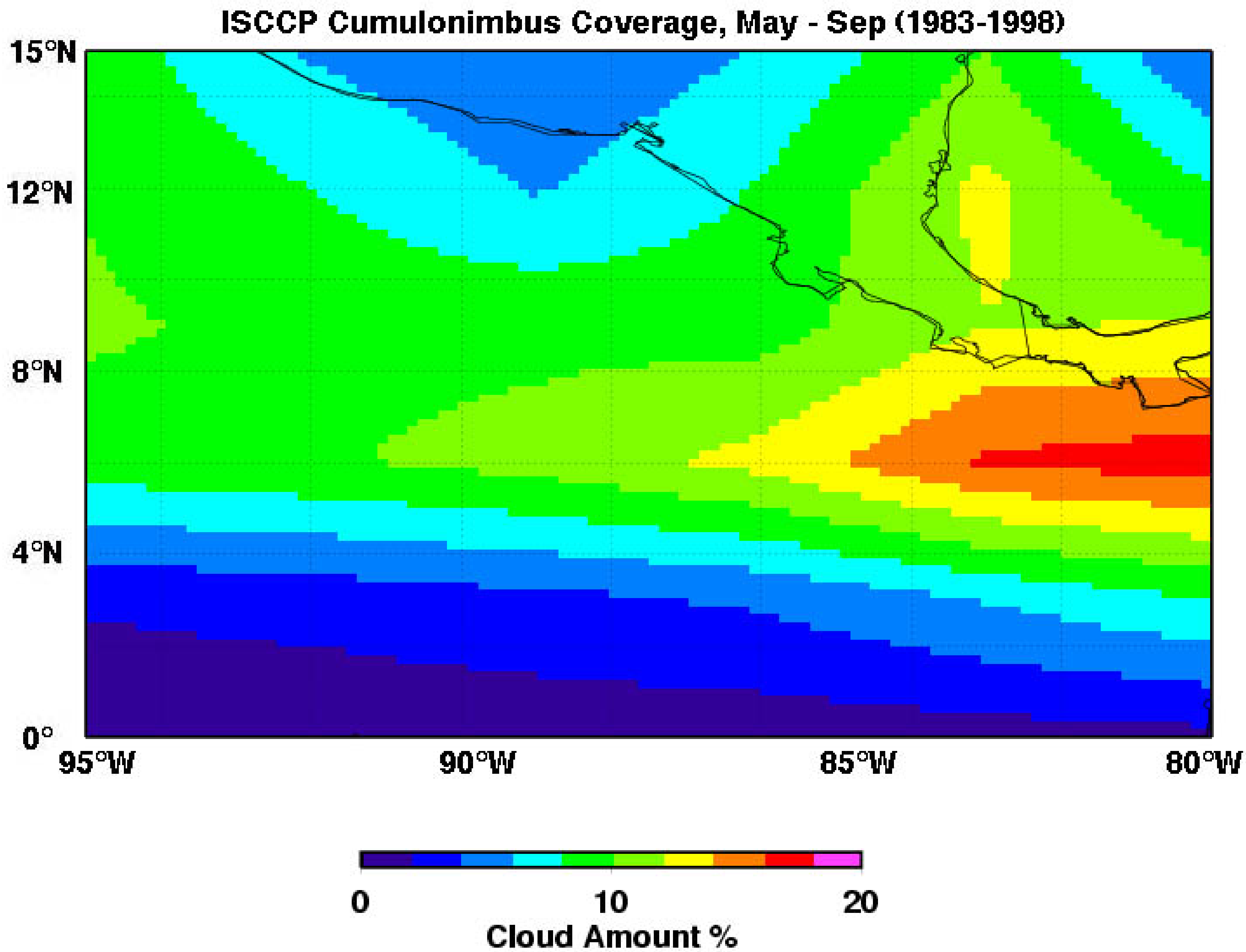
WB57 Radius of Operation

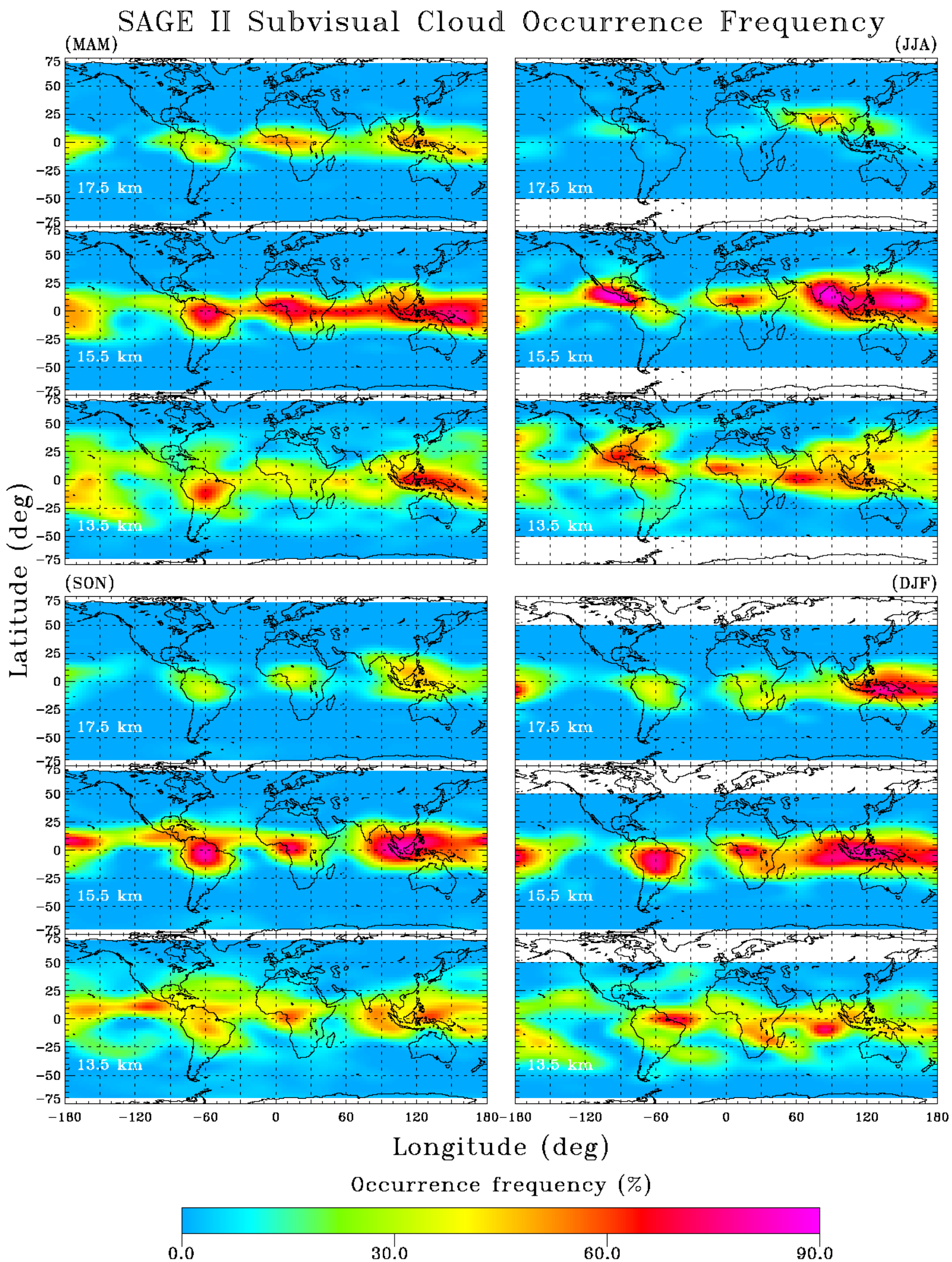
OLR < 220 W/m²

NCEP Reanalyses
100 hPa Temperature
(3-4K warm bias)

JULY




ISCCP Cumulonimbus Coverage, May - Sep (1983-1998)
15°N
12°N
8°N
4°N
0°
95°W
90°W
85°W
80°W
0
10
20
Cloud Amount %


SAGE II Subvisual Cloud Occurrence Frequency
(MAM)
(JJA)
(SON)
(DJF)
17.5 km
15.5 km
13.5 km
Latitude (deg)
Longitude (deg)
Occurrence frequency (%)
0.0
30.0
60.0
90.0

Example of flights in a summer mission-convection may be de-emphasized without radar

Number of multi-aircraft missions dedicated to goal	Goals (not prioritized) All flights include satellite validation
5	Deep maritime convection-anvils
2	Deep continental convection-anvils
5	Examine TTL properties (Clear sky)
3	Outflow sampling

OMI issues

Does OMI correctly measure cloud top height?

OMI would like to validate its cloud top retrieval heights.

Measurement strategy:

Instruments: down-looking lidar (ER-2)

Sampling strategy: measure cloud top height along OMI footprint.

HIRDLS

(CLOUDS/Aerosol – This remains the top priority for HIRDLS because relatively few cloud opportunities existed during the CR-AVE campaign, and because of a known HIRDLS height registration issue.)

A. Does HIRDLS *properly determine the location and altitude of thin (&SV) cirrus layers, cumulus anvil blow-off, opaque cloud tops and aerosol layers.*

Measurement strategy-

Instruments:lidar (ER-2)

Sampling strategy:Horizontal legs along footprint

HIRDLS

B. Does HIRDLS *correctly retrieve the location and characterization of aerosols and ice particles, including size distribution and composition.*

Does Hirdls correctly characterize the background aerosol size distribution (in part, as radiance correction verification).

Measurement strategy:

Instruments:lidar, in situ aerosol composition and particle size.

Sampling strategy:

Horizontal legs along footprint

HIRDLS

C. Does HIRDLS *correctly retrieve species vertical profiles - In order of priority: H_2O, CH_4, F11, F12, N_2O, Temperature (& CO_2 if possible), HNO_3 and O_3 to as high an altitude as possible.*

Measurement strategy:

Instruments:various constituents in situ, remote

Sampling strategy:

Horizontal and vertical legs along footprint

TES

A. Does TES properly retrieve constituent profiles of:

Nitric acid: High altitude aircraft HNO_3 measurements are one of the highest priorities for TES validation.

HDO:It is critical to obtain aircraft measurements of HDO at 700-750 hPa, where TES is most sensitive to this species. This is one of the highest priorities for TES validation.

Ozone:Lidar profiles of ozone under different atmospheric conditions during long, level DC-8 flight legs along Aura orbit track. CAFS measurements of ozone both above and, if possible below the aircraft. *In situ* aircraft profiles of ozone along the Aura orbit track. Ozonesonde profiles coordinated with TES special observations.

Carbon Monoxide: Similar to ozone, getting *in situ* tropospheric profiles under a variety of atmospheric conditions along the Aura flight track will be very useful for validation of TES measurements.

Water Vapor:measurements from a water vapor lidar. Additional balloon and aircraft measurements in the upper troposphere.

TES

B Does TES obtain correct cloud top heights?

Cloud top heights over thick, uniform cloud are desirable to validate TES cloud products. A second priority is cloud top pressure over uniform, thin clouds.

<u>Measurement strategy:</u>

Instruments:lidar profiles of cloud top heights

Sampling strategy: Horizontal legs along footprint

TES

C. Do TES L1B Radiances remain calibrated?

Measurement strategy:

Instruments: Cloud-free coincidences between S-HIS and TES will still be useful to TES for monitoring L1B calibration.

Sampling strategy:

Horizontal legs along footprint in cloud free conditions

MLS

A. *Does MLS properly retrieve the profiles of various species? H2O, RH, T, CO, O3, (HCl, HNO3, N2O lower priority)*

<u>Measurement strategy:</u>
Instruments: Various species
Sampling strategy:
Horizontal/vertical legs along footprint. Would like frostpoint sondes. DC-8 water vapor lidar (200-400 Pa). CO , O3 interest is in pollution or biomass burning episodes.

MLS

B. *Does MLS correctly retrieve IWP and IWC for thick clouds?*

<u>Measurement strategy:</u>

Instruments: Radar, microwave radiometer, particle size (30-500 μm), particle shape

Sampling strategy:

Horizontal legs for remote measurements and in situ vertical profiles, along footprint.

Summary

1. TC^4 is aimed at helping you, as well as augmenting your data.

2. We need to know soon if you want something else measured, so that the proper instruments are selected.

3. We will need feedback in the field:Where are your instruments looking everyday? What part of your field of view do you want to sample? Did something new come up as an issue?